



Beware of the Use of a Floating Ring in a Fluid-Film Bearing



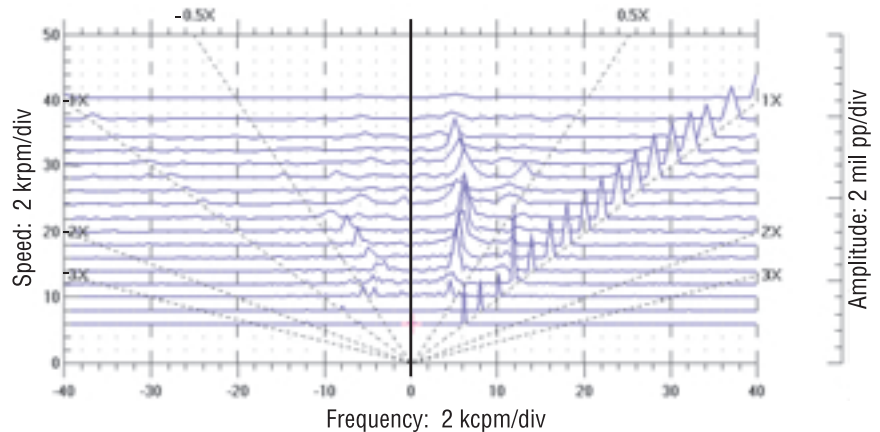
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Reverse vibrational components X to Y Rotation Forward vibrational components

Figure 1. Full spectrum cascade plot of a typical startup of a gas turbine with a fluid-film bearing with floating ring design.

Unloaded fluid-film bearings have the reputation as occasional sources of high vibration due to fluid-induced instability. When a bearing design becomes more complex, some additional types of instability may occur. In one type of fluid-film bearing (unimproved since its introduction 30 years ago), a floating ring separates the bearing from the journal. This brings up additional instabilities of the ring, in lateral and axial directions, plus provides unusual and difficult-to-predict motion of that ring. Not only do new instabilities appear, the old ones change their appearance in the presence of a floating ring, which leads to local lubricant starvation. Experimental results from the test rig, combined with data from the field, prove a floating ring in a fluid-film bearing to be useless and dangerous.

Fluid-film bearing with a floating ring

In this floating ring fluid-film bearing, the floating ring separates the bearing from the journal [1, 2]. The major objective for using a floating ring is a reduction of the lubricant speed gradient within the bearing. Particularly, it is assumed that the ring would rotate at a speed approximately half that of the journal. Additionally, a floating ring is supposed to “cure” such technical problems as misalignment.

Meanwhile, machinery with fluid-film bearings with the floating ring design has been continuously troubled, including a catastrophic failure of a gas turbine [1]. As a result of the failure, impellers of the compressor, as well as the proximity probe for phase measurement, were damaged. The brass thrust washer was destroyed (melted)

and oil within washer passages was charred.

During startup of the gas turbine, an unusual phenomenon was observed (Figure 1). Fluid whirl appeared at a frequency less than $\frac{1}{2}X$. As the machine came up in speed, the whirl disappeared. At operational speed there was no whirl.

The plot also indicates the presence of low frequencies, which are typical for floating ring design of a fluid-film bearing. The disappearance of the fluid whirl is unusual. At this point it is important to mention that fluid whirl can exist only under the condition of sufficient lubrication. In this case, however, the floating ring impaired oil delivery. The whirl ceased due to the centrifuge effect that pumps lubricant out of the bearing through radial ports

of the floating ring at high speeds (Figure 2). It resulted in lubricant starvation, thus in the whirl disappearance.

In order to clarify the observed phenomena, an experimental rig with a floating ring bearing was designed and built.

Experimental study of a fluid-film bearing with a floating ring

A vertical rotor consisting of a shaft and a journal, supported inboard by a bronze oilite bushing and outboard by a cylindrical oil-lubricated bearing with the floating ring, was driven by a 74.6 W (0.1 hp) electric motor (equipped with a speed controller) through a flexible coupling (Figure 3). A free spinner with a 2.4 g (0.08 oz) unbalance mass was installed next to the outboard bearing. The free spinner was driven by a separate 74.6 W (0.1 hp) electric motor (with a speed controller) through a flexible coupling. Both the rotor and the floating ring lateral motions were observed by sets of proximity probes in XY configuration. Three additional transducers were used to observe phases of the rotor, floating ring, and free spinner. Diametral clearances between the bearing/ring and journal/ring surfaces were 2.54×10^{-4} m (10 mils) each. Length and diameter of the shaft were 0.30 m (12 in) and 0.0095 m (0.375 in), respectively.

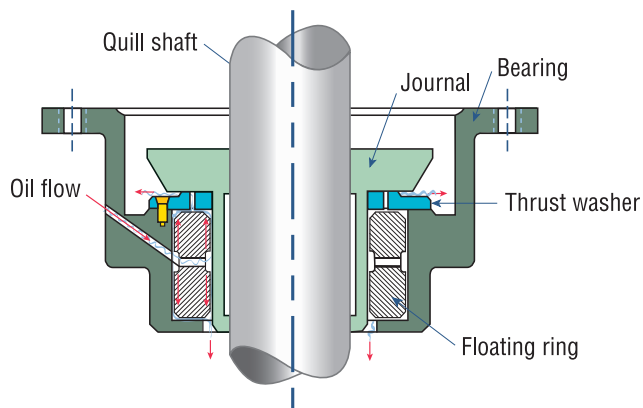


Figure 2. Journal/thrust combination.

Length and diameter of the journal were 0.038 m (1.5 in) and 0.029 m (1.125 in), respectively. Length of the floating ring was 0.025 m (1 in) and inner diameter of the bearing was 0.064 m (2.5 in).

The fluid-lubricated bearing was radially supplied with T10 oil from four laterally and axially symmetric ports. There were two circumferential grooves on the inner and outer sides of the floating ring and four symmetric radial holes to supply oil to the clearance between the journal/ring surfaces. The oil outlet was located at the upper axial side of the bearing. Masses of the shaft, journal, and floating ring were 0.17 kg (0.37 lb), 0.26 kg (0.57 lb), and 0.40 kg (0.88 lb), respectively. The hydrostatic oil pressure at the inlet was 13.8×10^3 Pa (2 psi).

Figure 4 illustrates axial and lateral instability of the centered position of

the floating ring. In either case, the fact of instability is determined by definition: If the ring is initially slightly displaced from the centered position in between the bearing and the journal in either axial or lateral direction, then oil flow will tend to increase the initial displacement.

The results of nonsynchronous perturbation of the rotor are presented below. During that testing, the unbalanced free spinner rotates with swept frequency while speed of the rotor is constant.

The full spectrum cascade plot of the shaft lateral vibrational response data during startup for the nonsynchronous run is presented in Figure 5. During the nonsynchronous run, the rotor of the experimental rig rotated at the constant speed of 2000 rpm, while the unbalanced free spinner was accelerating from 0 to 6000 rpm.

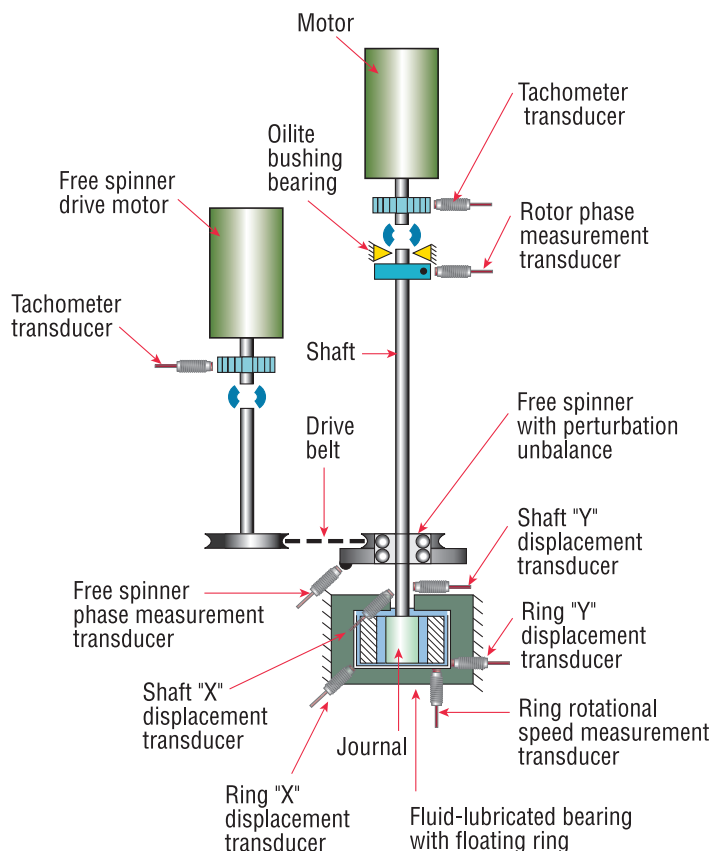


Figure 3. Experimental rig with the floating ring in a fluid-film bearing.

During the experiment, the following peculiarities of the floating ring design were observed:

- The floating ring does not rotate at approximately $\frac{1}{2}$ of the rotor speed. Instead, it rotates much slower – approximately 30 times slower than the rotor.
- Fluid-induced instability produces a forward component of lateral vibrational response with frequency far less than $\frac{1}{2}$ of the journal rotational speed. It corresponds to the whirl of the floating ring with frequency 3 to 4% of the journal rotational speed in the forward direction.
- The floating ring tends to press against the restraints, thus tampering with oil flow. Its “adhesive” ability is so high that at lower journal speeds, the ring does not rotate at all.

Summary

The floating ring adds peculiar features to the bearing. Its centered position between the journal and the bearing is unstable in both axial and lateral directions. It tends to obstruct the oil flow. In some cases, the latter can recover the journal from typical whirl. All the above indicate that using floating rings is a mistake. ☹

References:

1. Petchenev, A., Bently, D.E., Muszynska, A., Goldman, P., Grissom, R.L., “Case History of a Failure of a Gas Turbine with a Floating Sleeve Bearing,” *DETC99/VIB-8284*, 1999 *ASME Design Engineering Technical Conference*, September 12-15, 1999, Las Vegas, Nevada.
2. Petchenev, A., Bently, D.E., Muszynska, A., Goldman, P., “Experimental Study of a Fluid-Film Bearing With a Floating Ring,” *IMAC-XVII: A Conference & Exposition on Structural Dynamics*, February 8-11, 1999, Kissimmee, Florida, Vol. 1, pp. 283-289.

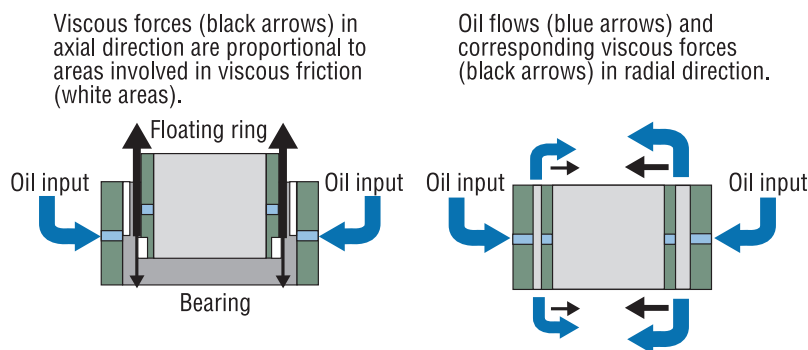


Figure 4. Illustration of axial and lateral instability of the floating ring's centered position.

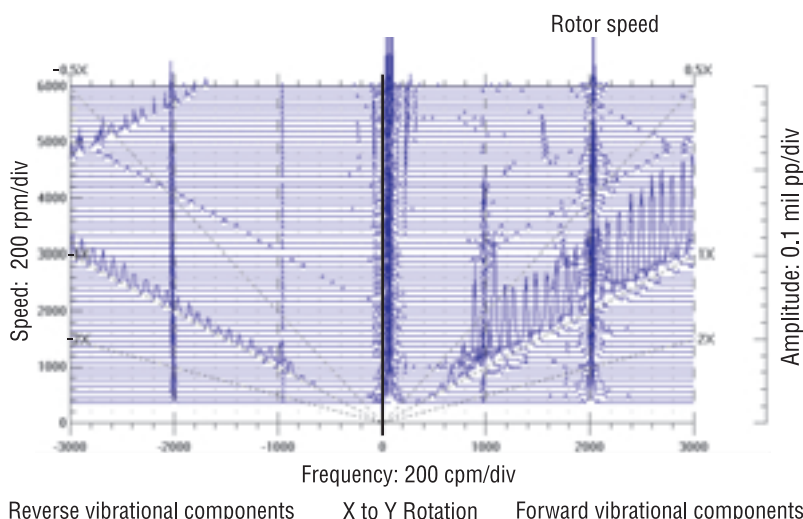


Figure 5. Full spectrum cascade plot of the shaft lateral vibrational response data during startup for the nonsynchronous run of the experimental fluid-film bearing with a floating ring.

ANNOUNCEMENT

Bently Nevada Wins CONTROL Magazine's Readers' Choice Award

The January 2000 issue of CONTROL featured the publication's Readers' Choice Awards for 2000. Once again, CONTROL surveyed its readers and asked them to identify the manufacturers that have provided them with the best instrumentation and control products. No company names were provided to the readers; they had to write in the name of a company. For the sixth year in a row, Bently Nevada placed #1 in the category of Vibration Instrumentation, this year receiving 62% of the votes. CONTROL also asked end-users to rate the customer service of their favorite vendors, and we are very pleased to have been listed as a vendor offering exceptional service. We are grateful to all of our customers that participated in the survey and voted for Bently Nevada. ☺